Human Reproduction, Vol.32, No.5 pp. 1064–1074, 2017
Advanced Access publication on February 15, 2017 doi:10.1093/humrep/dex025

human reproduction
ORIGINAL ARTICLE ***Infertility***

Estimating infertility prevalence in low-to-middle-income countries: an application of a current duration approach to Demographic and Health Survey data

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Submitted on September 29, 2016; resubmitted on December 8, 2016; accepted on January 24, 2017

STUDY QUESTION: Can infertility prevalence be estimated using a current duration (CD) approach when applied to nationally representative Demographic and Health Survey (DHS) data collected routinely in low- or middle-income countries?

SUMMARY ANSWER: Our analysis suggests that a CD approach applied to DHS data from Nigeria provides infertility prevalence estimates comparable to other smaller studies in the same region.

WHAT IS KNOWN ALREADY: Despite associations with serious negative health, social and economic outcomes, infertility in developing countries is a marginalized issue in sexual and reproductive health. Obtaining reliable, nationally representative prevalence estimates is critical to address the issue, but methodological and resource challenges have impeded this goal.

STUDY DESIGN, SIZE, DURATION: This cross-sectional study was based on standard information available in the DHS core questionnaire and data sets, which are collected routinely among participating low-to-middle-income countries. Our research question was examined among women participating in the 2013 Nigeria DHS ($n = 38\,948$). Among women eligible for the study, 98% were interviewed.

PARTICIPANTS/MATERIALS, SETTING, METHODS: We applied a CD approach (i.e. current length of time-at-risk of pregnancy) to estimate time-to-pregnancy (TTP) and 12-month infertility prevalence among women 'at risk' of pregnancy at the time of interview ($n = 7063$). Women who were 18–44 years old, married or cohabitating, sexually active within the past 4 weeks and not currently using contraception (and had not been sterilized) were included in the analysis. Estimates were based on parametric survival methods using bootstrap methods (500 bootstrap replicates) to obtain 95% CIs.

MAIN RESULTS AND THE ROLE OF CHANCE: The estimated median TTP among couples at risk of pregnancy was 5.1 months (95% CI: 4.2–6.3). The estimated percentage of infertile couples was 31.1% (95% CI: 27.9–34.7%)—consistent with other smaller studies from Nigeria. Primary infertility (17.4%, 95% CI: 12.9–23.8%) was substantially lower than secondary infertility (34.1%, 95% CI: 30.3–39.3%) in this population. Overall estimates for TTP >24 or >36 months dropped to 17.7% (95% CI: 15.7–20%) and 11.5% (95% CI: 10.2–13%), respectively. Subgroup analyses showed that estimates varied by age, coital frequency and fertility intentions, while being in a polygynous relationship showed minimal impact.

LIMITATIONS, REASONS FOR CAUTION: The CD approach may be limited by assumptions on when exposure to risk of pregnancy began and methodologic assumptions required for estimation, which may be less accurate for particular subgroups or populations.

Unrecognized pregnancies may have also biased our findings; however, we attempted to address this in our exclusion criteria. Limiting to married/cohabiting couples may have excluded women who are no longer in a relationship after being blamed for infertility. Although probably rare in this setting, we lack information on couples undergoing infertility treatment. Like other TTP measurement approaches, pregnancies resulting from contraceptive failure are not included, which may bias estimates.

WIDER IMPLICATIONS OF THE FINDINGS: Nationally representative estimates of TTP and infertility based on a clinical definition of 12 months have been limited within developing countries. This approach represents a pragmatic advance in our ability to measure and monitor infertility in the developing world, with potentially far-reaching implications for policies and programs intended to address reproductive health.

STUDY FUNDING/COMPETING INTERESTS: There are no competing interests and no financial support was provided for this study. Financial support for Open Access publication was provided by the World Health Organization.

Key words: infertility / time-to-pregnancy / developing countries / current duration / survival analysis

Introduction

Infertility in developing countries is an understudied concern in sexual and reproductive health, yet its impact can be staggering. An inability to conceive or bear children can result in being socially ostracized or divorced, and may have economic, mental or other health implications, such as adverse pregnancy outcomes and later-onset adult diseases (Basso *et al.*, 2003; Buck Louis *et al.*, 2011; Raatikainen *et al.*, 2010; Rouchou, 2013). While men and women are equally likely to be infertile, women are often blamed (Cui, 2010), and infertility has been associated with intimate partner violence (Ameh *et al.*, 2007; Dhont *et al.*, 2011a,b). Fears related to infertility may impact contraceptive use (Gebremariam and Addissie, 2014; Hyttel *et al.*, 2012), and infertility has been associated with high-risk sexual behaviors (Dhont *et al.*, 2011a,b). Limited access to infertility care in the developing world exacerbates these concerns (Asemota and Klatsky, 2015).

Obtaining accurate, country-level estimates of infertility prevalence is essential to address these issues, but is complicated by variation across studies in defining and in methods of estimating infertility (Gurunath *et al.*, 2011). Demographic approaches generally assess 5-year periods with no births (Larsen, 2003; Mascarenhas *et al.*, 2012a,b, Rutstein and Shah, 2004), yet such long exposure periods may be less clinically relevant. Clinical and epidemiological approaches commonly assess 12- or 24-month periods (World Health Organization, 2015), respectively, providing a more relevant measure to assess the need for services to enhance fertility. However, population-based infertility estimates for shorter durations are limited, and estimation approaches vary, obscuring true differences from those related to study design (Crawford *et al.*, 2015; Gurunath *et al.*, 2011; Skakkebaek *et al.*, 2016; Thoma, 2015).

Time-to-pregnancy (TTP) measures for monitoring couple fecundity permit examination of measures across all durations of exposure to the chance of pregnancy (Joffe, 2003; Olsen and Rachootin, 2003), and can help determine optimal timing of routine infertility investigations (Gnoth *et al.*, 2005), and can facilitate comparisons between population-based and clinical studies (Zegers-Hochschild *et al.*, 2009). The most common approach for assessing TTP at the population level is to ask couples to retrospectively report on the time it took to become pregnant. While this approach is relatively simple to implement, recall bias may impact reporting of this information, and this design will selectively under-represent infertile couples who do not become pregnant. In contrast, prospective cohort studies are often considered the gold standard for accurately estimating TTP, but are generally expensive and may be less feasible at a national level, particularly in resource-poor settings. Furthermore, these studies generally only capture couples consciously planning a pregnancy, who may differ in their pregnancy intention and recognition of fertility status compared with all couples at risk of pregnancy (Basso *et al.*, 2000; Greil *et al.*, 2010; Slama *et al.*, 2006). Finally, facility-based studies may capture only women with disproportionately long TTPs, given their greater likelihood of presenting for evaluation or treatment. Studies including all individuals at risk of pregnancy are, therefore, preferable.

The current duration (CD) approach is a feasible technique to estimate a population-level TTP distribution and infertility prevalence using a cross-sectional design. This approach samples couples at risk of pregnancy at the time of interview and determines their current length of time-at-risk of pregnancy (i.e. CD). A TTP-like distribution is estimated from the observed CDs using survival methods. Advantages of this approach over other retrospective or prospective designs are its ability to utilize a cost-efficient cross-sectional study design, while also including all couples at risk of pregnancy regardless of prior fertility history (e.g. childless couples who may be more likely to be infertile) or pregnancy intentions (e.g. couples who may be infertile but have stopped trying). Investigators have applied this technique in Europe and the USA (Keiding *et al.*, 2002; Louis *et al.*, 2013; Slama *et al.*, 2012; Thoma *et al.*, 2013). US estimates were consistent with those from prospective cohort studies, and over twice as high (15.5% versus 7.0%) as those derived from other cross-sectional estimation approaches (Thoma *et al.*, 2013).

The CD approach has not been applied to nationally representative data from a low- or middle-income country. Applying this technique to data from Demographic and Health Surveys (DHS) represents a pragmatic advance in the ability to measure infertility in low- or middle-income countries. Our objectives for this study were to apply a CD approach using standard information available from DHS data to generate a population-based TTP distribution and estimate infertility prevalence. We developed and applied our methodology to DHS data from Nigeria.

Materials and Methods

Study population and design

The 2013 Nigeria DHS used a stratified three-stage cluster sampling design (National Population Commission (NPC) [Nigeria] and ICF International, 2014). Our sample includes women 'at risk' of pregnancy at the time of interview, defined as women who were 18–44 years old, married or cohabitating, sexually active within the past 4 weeks and not currently using contraception (and had not been sterilized). We excluded women who: were currently pregnant, had given birth in the past 3 months or were postpartum amenorrheic; had used depot medroxyprogesterone acetate within the last 10 months; were menopausal or had a hysterectomy; had never menstruated; were missing information on timing of first sexual intercourse with current partner or did not have reproductive calendar data (Fig. 1).

CD measure

For each respondent, we calculated time-at-risk of pregnancy (a CD value), based on the following self-reported information: date of last live birth or pregnancy, duration of postpartum abstinence and amenorrhea for the most recent live birth, last contraceptive use, first cohabitation or intercourse with current partner, and date of interview (Table I, Fig. 1). We excluded respondents with CD values <0 (i.e. time not at risk of pregnancy). To account for potential under-reporting of first trimester pregnancies (Goldman and Westoff, 1980), we excluded information from the month of interview and preceding 2 months, which generates CD values spanning from the start of exposure to pregnancy risk up to 3 months prior to interview (i.e. a 3-month lag on CD values). We used the observed CD to estimate TTP and infertility based on the methods and definitions described below.

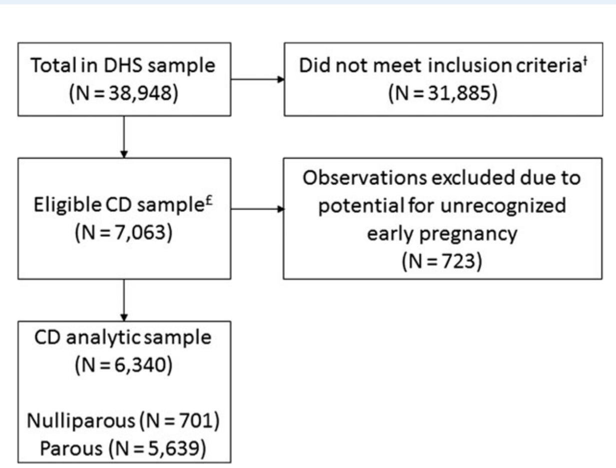

Figure 1 Eligibility criteria for the CD sample. †Excluded if: respondents were not between 18 and 44 years of age; were not married or cohabitating; were not sexually active in the last 4 weeks; were currently using contraception (or had been sterilized); were currently pregnant, had given birth in the past 3 months, or were postpartum amenorrheic; had used depot medroxyprogesterone acetate within the last 10 months; were menopausal or had a hysterectomy; had never menstruated; or were missing information related to the timing of first sexual intercourse with current partner or did not have reproductive calendar data, or had calculated CD values <0. £Eligible sample was determined from the minimum duration based on the time from most recent family planning use (or, if depot medroxyprogesterone acetate, most recent use of depot medroxyprogesterone acetate −10 months) (count = 167), most recent live birth minus postpartum abstinence or amenorrhea (count = 4225), most recent pregnancy that did not end in a live birth (count = 498), start of relationship with current partner (count = 716) or no events in the past 5 years (count = 1480) to the time at interview. Counts represent the number of times components of the CD values were equivalent to the final CD value, which may sum to over 7063 due to 'ties' between each of the components. CD, current duration.

Statistical analysis

Estimation of TTP and infertility prevalence using a CD approach

CD approaches infer an underlying distribution of the total (observed and unobserved) TTP based on the distribution of the observed time elapsed at interview (Keiding *et al.*, 2002; McLain *et al.*, 2014; van Es *et al.*, 2000; Weinberg and Gladen, 1986; Yamaguchi, 2003). The CD values are commonly referred to as backwards recurrence times. Since respondents remain at risk of pregnancy and are not followed up after the interview, estimates for time-at-risk of pregnancy are inherently length-biased (i.e. couples who take longer to achieve pregnancy are over-represented) and right-censored (i.e. total duration of exposure to pregnancy risk is never observed) (Lum *et al.*, 2015). The CD approach accounts for these issues under the following assumptions: the start of exposure to pregnancy risk occurs at a constant rate over calendar time among couples within the population (i.e. stationarity assumption), that the probability a couple is at risk of pregnancy when interviewed is proportional to the total length of her time-at-risk of pregnancy, and the distribution of TTP is independent of calendar time (Keiding *et al.*, 2002). We derived the analytic sample and CD measures using Stata 12 (StataCorp LP, College Station, TX, USA).

The CD approach estimates a population-based survival function for TTP or end of exposure to pregnancy risk for other reasons, such as relationship end or contraceptive initiation, but cannot distinguish whether the CD ended in a pregnancy or for other reasons. We used parametric survival methods (weighted to account for survey design) assuming a generalized gamma distribution and calculated 95% CIs using bootstrap methods (all analyses used 500 bootstrap samples) (Keiding *et al.*, 2002; Slama *et al.*, 2012; Yamaguchi, 2003). To assess model fit, we compared the weighted observed versus model-based predicted distributions for the generalized gamma distribution (McLain *et al.*, 2014). We also assessed Log-normal and Pareto distributions and a piecewise constant model. We assessed model fit statistics for the overall distribution, by parity, and for the various subgroups. Overall, we found that the generalized gamma consistently fit the data best, or close to best, for all the different groups. Consistent with other studies (Slama *et al.*, 2012; Thoma *et al.*, 2013), we censored analyses after 36 months (Bradley *et al.*, 2015).

Summary measures

We interpret the TTP summary estimate as the proportion of couples not yet pregnant by *N* months at-risk of pregnancy. We report 12-month infertility estimates (and 95% CIs) of TTP >12 months, consistent with the World Health Organization's clinical definition of infertility ('the failure to achieve a clinical pregnancy after 12 months or more of regular unprotected intercourse.') (Zegers-Hochschild *et al.*, 2009). An advantage of the CD approach and TTP measures in general is that it enables assessment of varying thresholds, or definitions, of infertility. Therefore, we also report 24- and 36-month infertility estimates (and 95% CIs) to permit comparisons with other studies using different durations, and examined multiple subgroup analyses to assess the robustness of our assumptions (Table II). Models were fitted using R software (Vienna, Austria) (R Core Team, 2015) and example R-code for fitting the model and sample data is provided in the Supplementary Data.

Ethical approval

This paper is a secondary data analysis of publically available DHS data and did not require ethical approval. All participants provided oral informed consent prior to the DHS interview (National Population Commission (NPC) [Nigeria] and ICF International, 2014).

Table I Calculation of CD by respondent characteristics.

Respondent characteristic	CD calculation
Women who previously used birth control and did not have a pregnancy since most recent use of birth control	Date of interview minus date of last birth control method used[a]
Women who have been pregnant and either never used birth control or did not use birth control after most recent live birth	Date of interview minus [date of end of last live birth – maximum (duration of postpartum abstinence or duration of postpartum amenorrhea)]
Women who have been pregnant, but for whom the pregnancy did not end in a live birth, and who either never used birth control or did not use birth control after most recent pregnancy not ending in a live birth	Date of interview minus date of end of last pregnancy
Nulligravid women who never used birth control	Date of interview minus either: • Date of first cohabitation with current partner[b] (88% of analytic sample) or • Date of first intercourse with current partner (asked only of a subset of women), for women who had been in more than one union (12% of our analytic sample).

CD, current duration.
[a]If the last method used was depot medroxyprogesterone acetate, we subtracted a 10-month washout period from the CD.
[b]Some women may have a longer duration of exposure to pregnancy risk than that captured by using date of first cohabitation (e.g. due to premarital sex), but at least 71% of respondents reported that their first sexual experience occurred when they first started living with their current husband or partners. Furthermore, due to responses coding, this is likely an underestimate: a minority of respondents answered the question about age at first sex by providing a specific age. If the age provided was also the age of first cohabitation, 71% is an underestimate, which makes our assumptions even more conservative.

Table II Subgroup analyses.

Subgroup	Definition and rationale
Age 35–44 years	Older women (aged 35–44 years); to assess the impact of age on infertility.
Polygynous relationship (or do not know/missing)	Women in a polygynous relationship (or with missing data), who may differ by the frequency of sexual activity with a partner or be at higher risk for sexually transmitted infections; as men in some sub-Saharan African cultures are justified in taking a second wife if his first is infertile.
Wants another birth soon	Women who report wanting a birth between 'now' and within 9 months as a proxy for currently trying for a pregnancy.
Coital frequency >95x/yr	Women who report higher coital frequency (≥95 acts of intercourse in the 12 months preceding the interview); to assess the impact of varied intensity of exposure to risk of pregnancy.
Correct knowledge of the fertile period	Women who know chances of pregnancy are greatest halfway between two menstrual periods; to assess how knowledge of the fertile window impacts infertility.

Results

Sample characteristics

Table III displays characteristics of all women in the 2013 Nigeria DHS study, compared with those in our sample. The DHS included women aged 15–49 years, and we restricted the sample to ages 18–44 years; ~22% were 18–24 years, 41% were 25–34 years and 37% were 35–44 years. We also restricted to women who were currently married (98%) or living with a partner (2%). Our sample was more likely to be parous (12% of included versus 33% of excluded women had never borne children), to have no education (56% versus 34%), and to be illiterate (65% versus 42%). Most of our analytic sample reported living in a rural area (68%) and practicing Islam (69%), and most had never used contraception (92%) despite high awareness of modern contraceptive methods (79%). Only ~20% of women in either sample correctly identified the fertile period. Ever terminating a pregnancy was reported by 14% of our sample. Approximately ¼ of women (regardless of inclusion) were currently breastfeeding, and most (63–68%) were not in a polygynous relationship. Women in our analytic sample were more likely to want another child within the next 2 years (60% versus 17%), and the proportion of women whose husband wanted more children than her was similar regardless of inclusion (44% versus 39%). Women in our sample reported higher sexual frequency as compared with excluded women.

Table IV displays differences by parity and fertility intentions in our sample. Nulliparous women were younger, had higher education and were more literate, were less likely to be in a polygynous marriage, and had lower sexual frequency. They were more likely to want a child in the near future, and less likely to have a husband who wanted more children than the female partner. Women who wanted another birth soon were younger, more educated and more likely to have terminated a previous pregnancy.

TTP and infertility prevalence estimates

Figure 2 displays TTP summary distributions up to 36 months. Median estimated TTP was 5.1 (95% CI: 4.2–6.3) months. Infertility prevalence, defined as the estimated percentage of couples (including nulliparous and parous) who were not pregnant by 12 months, was 31.1% (95% CI: 27.9–34.7%) (Table V). Primary infertility estimates

Table III Characteristics of women in the 2013 Nigeria DHS data set (total) and by eligibility for the CD sample.

Characteristics	Total DHS population (*N* = 38 948)		CD group				*P*-value[a]
			Not eligible (*n* = 31 885)		Eligible (*n* = 7063)		
	N	%[b]	*N*	%[b]	*N*	%[b]	
Age at interview (years)							0.00
15–17	4946	12.5	4946	15.4	n/a	n/a	
18–24	9673	24.9	8218	25.6	1455	22.0	
25–34	12 410	32.4	9476	30.4	2934	41.2	
35–44	8364	21.4	5690	17.9	2674	36.8	
45–49	3555	8.8	3555	10.8	n/a	n/a	
Marital status							
Married	26 403	69.4	19 501	62.8	6902	98.2	0.000
Living with partner	871	2.0	710	2.1	161	1.8	
Other (never in union, widowed, divorced, separated)	11 674	28.5	11 674	35.1	n/a	n/a	
Total children ever born							0.000
0	11 497	29.1	10 670	33.0	827	12.2	
1	4399	11.3	3478	10.9	921	13.2	
2–4	11 501	30.3	8782	28.3	2719	38.8	
5–7	7738	19.6	5968	18.4	1770	24.6	
8–16	3813	9.7	2987	9.4	826	11.3	
Urban	15 545	42.1	13 405	44.5	2140	31.8	0.000
Maternal education							0.000
No education	13 740	37.8	10 046	33.7	3 694	55.7	
Primary	7104	17.3	5768	17.3	1336	17.5	
Secondary	14 407	35.8	12 859	39.3	1548	20.5	
Higher	3697	9.1	3212	9.8	485	6.4	
Illiterate	17 186	46.1	12 820	41.9	4366	64.5	0.000
Religion							0.000
Catholic	4081	11.1	3623	12.1	458	7.0	
Other Christian	15 757	35.7	13 782	38.6	1975	23.2	
Islam	18 578	51.7	14 064	47.9	4514	68.5	
Traditionalist/other/missing	532	1.4	416	1.4	116	1.5	
Ever terminated a pregnancy (self-reported)	4114	10.8	3083	10.1	1031	13.8	0.000
Knows a modern method of contraception	32 882	83.8	27 222	84.9	5660	79.2	0.000
Never used contraception	29 528	76.0	23 072	72.2	6456	92.2	0.000
Currently breastfeeding	9782	25.4	8147	25.9	1635	23.4	0.001
Non-polygynous	18 124	66.8	13 697	68.2	4427	62.9	0.000
Fertility preferences							0.000
Wants within 2 years	9282	25.4	5103	17.2	4179	60.1	
Wants after 2+ years	10 550	27.4	9305	29.8	1245	17.0	
Wants, unsure of timing	8199	20.0	8073	24.2	126	1.7	
Undecided	3243	8.2	2679	8.3	564	7.8	
Wants no more	6208	15.1	5434	16.3	774	10.0	
Sterilized	98	0.3	98	0.3	n/a	n/a	
Declared infecund	1100	3.0	948	3.1	152	2.3	
Missing	268	0.7	245	0.8	23	0.3	

Continued

Table III *Continued*

Characteristics	Total DHS population (N = 38 948)		CD group				P-value[a]
			Not eligible (n = 31 885)		Eligible (n = 7063)		
	N	%[b]	N	%[b]	N	%[b]	
Husband wants more children than wife	10 635	39.9	7606	38.5	3029	43.8	0.000
Sexual frequency in last year with most recent partner							0.000
1–20	7449	23.4	6634	27.5	815	10.5	
21–40	5316	15.8	4224	16.7	1092	12.9	
41–60	4668	14.7	3391	14.1	1277	16.5	
61–80	2583	8.5	1803	7.9	780	10.6	
80–94	771	2.6	548	2.5	223	3.1	
95+	8709	33.6	5920	29.8	2789	45.4	
DK/missing	494	1.4	407	1.6	87	1.0	
Correct knowledge of fertile period	8479	20.4	7037	20.7	1442	19.3	0.000

[a]*P*-values derived from Pearson's Chi-square test.
[b]Percentages are weighted.
DHS, Demographic and Health Survey; DK, don't know.

(i.e. nulliparous women) (17.4%, 12.9–23.8%) were substantially lower than secondary infertility estimates (i.e. parous women) (34.1%, 30.3–39.3%). TTP >24 months was 17.7% (95% CI: 15.7–20%) overall, 10.0% (95% CI: 7.0–14.3%) among nulliparous and 19.2% (95% CI: 17.1–22.1%) among parous women. TTP >36 months was 11.5% (95% CI: 10.2–13%) overall, 6.8% (95% CI: 4.6–10%) among nulliparous and 12.3% (11.0–14.1%) among parous women.

Subgroup analyses of 12-month infertility prevalence

Among the 55% of women who reported wanting another birth soon, the 12-month infertility estimate increased to 39.7% (34.4–47.4%), driven largely by parous women (51.0%, 42.4–81.1%). Women who reported higher coital frequency had higher infertility estimates (37.1%, 31.0–50.1%), particularly nulliparous women 37.3% (23.1–90.6%), although this estimate had wide 95% CI. Nulliparous women with correct knowledge of the fertile period had slightly lower point estimates but a wider 95% CI for infertility (14.3%, 7.0–54.8%) compared to all nulliparous women. Conversely, parous women with correct knowledge of the fertile period had slightly higher estimates (38.9%, 30.7–62.4%) compared to all parous women, but overlapping 95% CIs. In the total sample, older women had a higher infertility prevalence estimate (44.3%, 95% CI: 37.4–58.1%), driven largely by parous women (there were few older nulliparous women). Being in a polygynous relationship showed slightly higher estimates among nulliparous women (21.2%, 11.2–61.4%), and slightly lower estimates among parous women (32.6%, 27.6–39.6%), although 95% CIs overlapped.

Discussion

To the best of our knowledge, these infertility prevalence estimates are the first generated using a CD approach in a lower middle-income country. We estimate that close to one-third of Nigerian couples at risk of pregnancy will have difficulty conceiving within 12 months and that these estimates drop substantially to 17.7% and 11.5% by 24- and 36-month durations, respectively. We also show that the 12-month prevalence of secondary infertility (34% among parous women) was double that of primary infertility (17% among nulliparous women).

In subgroup analyses, older age was associated with substantially higher infertility estimates, as expected, while being in a polygynous relationship had little effect. Estimates were substantially higher among women (especially parous women) who reported (at the time of interview) wanting a baby soon. This desire may reflect having struggled to get pregnant (a subsequent time, for parous women), which may be associated with higher infertility; though we cannot confirm whether fertility intentions at the start of the period of becoming at-risk for pregnancy are the same as those at the time of interview. This issue of temporality is inherent to cross-sectional designs, and is also applicable to subgroup analyses on coital frequency and correct knowledge of the fertile period. Higher coital frequency in the past year was also associated with greater infertility, particularly among nulliparous women. While seemingly paradoxical, this may reflect greater motivation to achieve pregnancy if potential infertility is perceived, potential misreporting of contraceptive use with sexual activity, or lack of concurrence between reported coital frequency in the past year and duration of exposure to pregnancy risk, particularly for very short or long durations. Given the temporality issue noted above, measures to assess coital frequency per month could better capture this relationship, but are currently unavailable within the DHS. Correct knowledge of the fertile window was associated with an expected decrease in infertility for nulliparous women, while their parous counterparts unexpectedly had slightly higher estimates (95% CIs were wide for both groups). Fertility awareness-based methods of family planning may not be well-captured in DHS contraceptive calendar data (Rossier *et al.*, 2014); some women who reported correct knowledge of the fertile period might have been avoiding intercourse during the fertile window without having been recorded as using contraception. Additionally, reporting of knowledge

Table IV Characteristics of women in the CD sample, by parity and fertility intention status.

Characteristics	Nulliparous ($N = 827$)		Parous ($N = 6236$)		*P*-value	Does not want another birth soon ($N = 3277$)		Wants another birth soon ($N = 3786$)		*P*-value[a]
	N	%[b]	*N*	%[b]		*N*	%[b]	*N*	%[b]	
Age at interview (years)					0.000					0.000
18–24	404	51.9	1051	17.8		577	19.0	878	24.4	
25–34	299	33.7	2635	42.2		1265	38.1	1669	43.7	
35–44	124	14.4	2550	40.0		1435	42.9	1239	31.9	
Maternal education					0.000					0.000
No education	366	48.3	3328	56.7		1738	56.8	1956	54.8	
Primary	111	13.4	1225	18.0		688	19.7	648	15.7	
Secondary	235	26.2	1313	19.7		697	19.3	851	21.4	
Higher	115	12.1	370	5.6		154	4.2	331	8.1	
Illiterate	412	53.8	3954	65.9	0.000	2096	67.1	2270	62.3	0.000
Ever terminated a pregnancy (self-reported)	133	14.2	898	13.8	0.952	353	10.2	678	16.8	0.000
Non-polygynous	594	71.3	3833	61.7	0.000	2042	62.1	2385	63.5	0.534
Sexual frequency in last year with most recent partner					0.000					0.000
1–20	134	14.8	681	9.9		457	12.6	358	8.7	
21–40	134	15.5	958	12.6		515	12.8	577	13.0	
41–60	141	18.0	1136	16.3		615	17.4	662	15.8	
61–80	80	9.3	700	10.8		312	8.9	468	12.0	
80–94	26	2.9	197	3.1		100	3.3	123	2.8	
95+	297	38.2	2492	46.4		1248	44.2	1541	46.5	
DK/missing	15	1.3	72	1.0		30	0.8	57	1.2	
Fertility preferences					0.000					0.000
Wants within 2 years	743	89.9	3436	56.8		393	12.5	3786	100	
Wants after 2+ years	17	1.7	1228	19.1		1245	37.9	0	0	
Wants, unsure of timing	16	2.0	110	1.7		126	3.9	0	0	
Undecided	25	3.1	539	8.5		564	17.5	0	0	
Wants no more	0	0	774	11.4		774	22.3	0	0	
Declared infecund	25	3.3	127	2.2		152	5.1	0	0	
Missing	1	0	22	0.4		23	0.7	0	0	
Husband wants more children than wife	293	36.3	2736	44.8	0.004	1365	42.4	1664	44.8	0.067
Correct knowledge of fertile period	183	20.3	1259	19.2	0.000	639	18.3	803	20.1	0.044

[a]*P*-values derived from Pearson's Chi-square test.
[b]Percentages are weighted.

of the fertile window at the time of interview may reflect a change in knowledge after having struggled to get pregnant. Since the associations discussed above are bivariate, multivariate adjustment may elucidate the simultaneous impact of these factors.

Our estimates are consistent with other infertility estimates from the region. A cross-sectional study using systematic random sampling of women in rural Nigeria estimated an infertility prevalence of 30.3%, defined as a self-reported inability to achieve pregnancy after 18 months of regular coitus (Adetoro and Ebomoyi, 1991). Older estimates from DHS and World Fertility Survey data (using a 5–7 year definition of infertility) ranged between 12.6% (Ericksen and Brunette, 1996) and 36% (Larsen, 2000). Unlike high-income countries, primary infertility estimates are generally lower than for secondary infertility in low- or middle-income countries, consistent with our findings (Larsen, 2000). In Nigeria, infection is a major cause of infertility, including from sexually transmitted infections and postabortal or puerperal sepsis (Araoye, 2003; Panti and Sununu, 2014). A prospective facility-based study in Nigeria suggested that two-thirds of all infertility cases were secondary (Panti and Sununu, 2014). Recent estimates using population-based surveys and 5-year exposure periods reported primary infertility among women exposed to the risk of pregnancy (20–44 years) in Nigeria of 3.1% (2.6–3.8) and secondary infertility 13.8% (11.8–15.9) in 2010 (Mascarenhas *et al.*, 2012b). To the best of our knowledge, only one other study has assessed TTP using a retrospective pregnancy-based design in an African

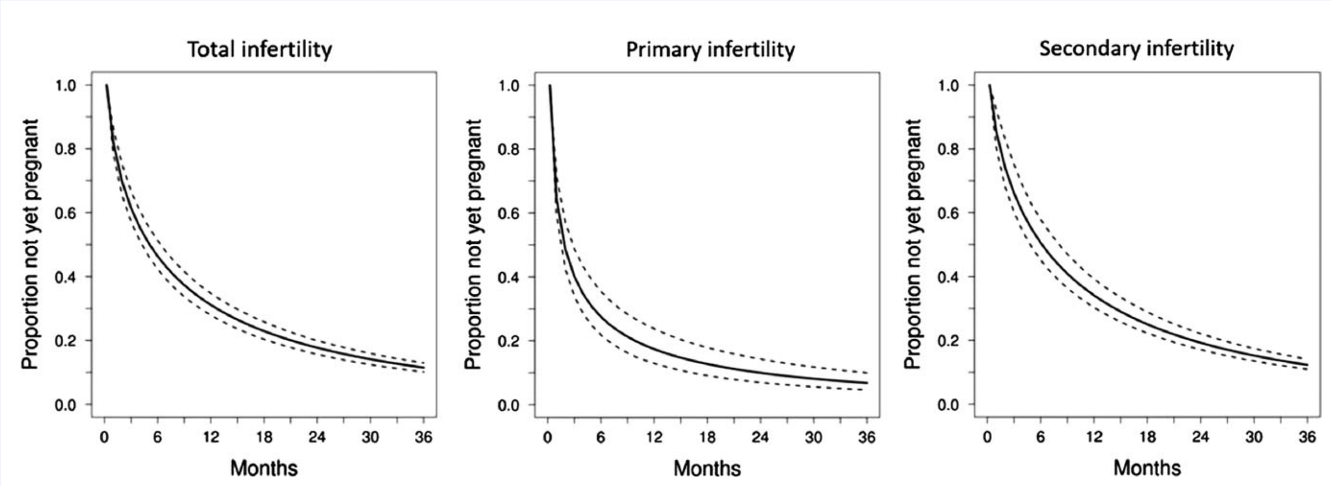

Figure 2 Survival function for TTP or end of pregnancy attempt estimated using a CD approach. Solid line represents the curves for the estimated TTP; dotted lines represent the 95% CIs around those curves, TTP, time-to-pregnancy.

Table V Twelve-month infertility prevalence estimates among women aged 18–44 years in Nigeria based on a CD approach.

Analytic population	Parous + nulliparous (total infertility)[a]		Nulliparous-only (primary infertility)[a]		Parous only (secondary infertility)[a]	
	N	Infertility prevalence (95% CI)	*N*	Infertility prevalence (95% CI)	*N*	Infertility prevalence (95% CI)
Total (all female DHS participants who met our analytic eligibility criteria)	6340	31.1 (27.9–34.7)	701	17.4 (12.9–23.8)	5639	34.1 (30.3–39.3)
Subgroup analyses						
Age 35–44 years	2525	44.3 (37.4–58.1)	n/a	n/a	2407	45.1 (37.9–56.7)
Polygynous relationship (or DK/missing)	2391	31.5 (27.0–38.8)	204	21.2 (11.2–61.4)	2187	32.6 (27.6–39.6)
Wants another birth soon[b]	3456	39.7 (34.4–47.4)	627	18.1 (13.2–24.1)	2829	51.0 (42.4–81.1)
Coital frequency >95x/yr	2560	37.1 (31.0–50.1)	280	37.3 (23.1–90.6)	2280	37.8 (31.9–55.5)
Correct knowledge of the fertile period	1277	35.0 (27.4–56.4)	147	14.3 (7.0–54.8)	1130	38.9 (30.7–62.4)

[a]Estimates based upon a parametric survival function using generalized gamma and 95% CI based on bootstrap methods. CDs >36 months were censored at that value. Infertility prevalence estimates at 24 and 36 months are provided in the text.
[b]Definition of 'soon' ranges from 'now' to within 9 months.
n/a, not available due to small cell sizes.

population (Bello *et al.*, 2010) and found a 12-month infertility prevalence of 32% and a median TTP of 6 months among a nationally representative sample of reproductive-aged women in South Africa—consistent with our estimate of 31% and median TTP of 5.1 months. In addition to consistency with other studies, the strengths of our approach include using publically available data to provide nationally representative estimates of TTP and infertility at varying thresholds, rather than an arbitrary cut-off, and avoiding the limitations of pregnancy-based retrospective and prospective designs discussed above.

Few studies have estimated infertility with nationally representative data using a CD approach; all have been in high-income countries or settings with high contraceptive prevalence rates (Louis *et al.*, 2013; Slama *et al.*, 2012; Thoma *et al.*, 2013). A French study reported a 12-month infertility estimate of 24% (95% CI: 19–30%), and 26% (95% CI: 15–36%) among nulliparous women. Estimates in US women were somewhat lower: 16% at 12 months (95% CI: 8.6–27.5%), and 24% (95% CI: 12.4–43.5%) among nulliparous women. Unlike our study and estimates from France, US estimates were based on individuals who reported trying to conceive, rather than all women at risk of pregnancy. Due to later ages at first birth in the USA and France (Mathews and Hamilton, 2016), nulliparous women in those countries may be older than those in our sample, which may explain our lower point estimates among nulliparous women in Nigeria (although 95% CIs overlapped).

Limitations

The CD approach depends upon accurate identification of when exposure to risk of pregnancy begins. Unlike the US National Survey of

Family Growth (Thoma et al., 2013), DHS questionnaires do not ask respondents how long they have been at risk of pregnancy (or have been trying to conceive). Therefore, our analysis may be limited by the need to make assumptions about when exposure to risk of pregnancy began. This is more challenging in parous women, particularly in societies where breastfeeding for long durations is common, and may impact regular menstrual cycle patterns. We also restricted inclusion to currently married or cohabitating couples, under the assumption that others were less likely to desire pregnancy or be having regular, unprotected sexual intercourse. In the full DHS sample, <4% of women not married or cohabitating desired pregnancy in the near future, versus 27% of their married or cohabitating counterparts. We assumed that being coded menopausal in DHS data was sufficient to accurately exclude menopausal women. We did not exclude women based on time since last menses, since some women with fertility issues may have irregular cycles, and should be included. Since <1% of our analytic sample reported no menses in the previous year, misclassification is unlikely to substantially affect our results, but most (78%) of those women were older (40–44) and not coded in DHS as menopausal. Although likely rare in this setting, we lack information on couples undergoing infertility treatment and cannot evaluate its potential impact on our estimates.

Other assumptions may result in incorrectly excluding women at risk of pregnancy. For example, we exclude women who report contraceptive use, but a woman may be at risk of pregnancy if she has multiple sexual partners and does not use that contraceptive method with all partners. We anticipate little impact on our results, as overall contraceptive prevalence in Nigeria is low, and only 1% of our sample reported multiple partners. Limiting to married or cohabiting couples may have excluded women who are no longer in a relationship due to being blamed for infertility. Our analytic sample included a 3-month lag on the CD values to account for unrecognized pregnancies (Goldman and Westoff, 1980). While this may have excluded some women at risk of pregnancy, it reduces bias resulting from delays in pregnancy recognition (Slama et al., 2006).

Finally, a limitation of the CD approach, inherent to all TTP studies, is that pregnancies resulting from contraceptive failure are not included, which may bias estimates if this population represents a more fertile population, particularly if contraceptive failure rates are high. Investigators have proposed methods to examine these biases (Key et al., 2009). In addition, the estimation of TTP relies on the assumptions of stationarity, which is likely to hold for shorter intervals (i.e. <36 months) examined in our analysis. Furthermore, the estimation is dependent on the start of the at-risk period and relies on appropriate distributional specification. In this case, we applied the generalized gamma distribution, which contains the Weibull, Log-normal, Gamma and Exponential as special cases.

Implications for future research

This methodology allows for estimation of total, primary and secondary infertility and may represent robust estimates for comparison over time and across countries. However, behavioral factors such as intensity of pregnancy-achieving behaviors (often correlated with parity), contraceptive use or use of infertility treatment may vary across populations and impact estimates (Basso et al., 2000; Joffe, 2003; Slama et al., 2006). Monitoring TTP among first births/pregnancies (or nulliparous couples) may reduce these potential biases (Olsen and Rachootin, 2003). Comparing results from this approach with results from prospective surveys in a low- or middle-income country would further establish validity. Furthermore, including questions in nationally representative surveys that can differentiate time trying to conceive (i.e. 'How many months (or years) have you been having sexual intercourse with the intention of becoming pregnant?') from all time-at-risk of pregnancy (as used in our analysis) may address some potential biases. Providing TTP measures for other countries using the same standard set of questions would permit cross-country comparisons and monitoring of infertility trends over time. Next steps include applying this method to DHS data from countries with different demographic and contraceptive profiles than Nigeria to determine if this approach is applicable to other countries with available DHS data.

Conclusion

Our analysis suggests that information available in DHS permits calculation of infertility prevalence, but may be improved with the addition of questions noted above. Successfully applying the CD approach to DHS data has potentially far-reaching implications for obtaining infertility estimates in low- or middle-income countries in a cost-effective manner, as DHS data are nationally representative and widely available. Our analysis suggests that a substantial percentage of couples in Nigeria may be struggling with infertility. The capability of health systems and societies to address this issue, including its health, social and economic sequelae, requires attention. In the new era of sustainable development goals where equity is at its core, robust and actionable estimates of infertility will be crucial in focusing commitment, services and resources at the global and country level to the neglected issue of infertility in low-income settings.

Supplementary data

Supplementary data are available at *Human Reproduction* online.

Authors' roles

C.B.P., C.M.C., O.T. and M.E.T. conceived of and designed the analysis. C.B.P., C.M.C., A.C.M. and M.E.T. analyzed the data. A.C.M. contributed analytic tools. C.B.P. wrote the first draft of the manuscript and all authors contributed to the writing and approve of the final version of the manuscript.

Acknowledgements

We thank Trevor Croft and Dr Rebecca Callahan for their technical assistance with Stata code for handling contraceptive calendar data, Dr Sarah E.K. Bradley for insights on DHS data quality and Dr Germaine Buck Louis for feedback on an earlier draft of this manuscript.

Funding

We completed this work on personal time, without financial support. The authors would like to acknowledge World Health Organization for providing financial support to cover Open Access publication fees

for this manuscript, in order to make this work more widely available to readers around the world.

Conflict of interest

None declared.

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